UCRL-JC-134777
PREPRINT

Initial Statistical Evaluation of ARAC COAMPS Forecasts

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This paper was prepared for submittal to the
American Nuclear Society 7th Topical Meeting on Emergency Preparedness and Response
Santa Fe, NM
September 14-17, 1999

June 30, 1999

Lawrence Livermore National Laboratory

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SUMMARY
This paper describes a system which evaluates forecasts from the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), generated by the Atmospheric Release Advisory Capability (ARAC) at the Lawrence Livermore National Laboratory (LLNL). The system generates statistics for forecasts of varying lengths by comparing vertical profiles forecasted by COAMPS with rawinsonde soundings. Results obtained using the system are shown, including results incorporating observations from an intensive field experiment.

I. BACKGROUND
ARAC models the dispersion of hazardous materials in the atmosphere for emergency response applications. The ARAC system[1] permits use of a variety of meteorological data sources as input to its dispersion models. Within the past year, several ARAC responses[2,3,4] have shown the benefit of using meteorological data generated by global or regional scale models.

COAMPS[5] is a non-hydrostatic mesoscale prognostic model developed by the Naval Research Laboratory (NRL). NRL has provided the COAMPS model to LLNL for use at ARAC. COAMPS is operated for Navy operations by the Navy's Fleet Numerical Meteorological and Oceanographic Center (FNMOC).

COAMPS allows use of up to seven levels of nests, with each inner nest a factor of three higher resolution than the next outer nest. Boundary conditions for COAMPS runs are drawn from forecasts of the Navy Operational Global Atmospheric Prediction System (NOGAPS), provided to ARAC by FNMOC. ARAC generally runs COAMPS in a data-assimilation mode, with a run starting every 12 hrs based on the previous run's 12 hr forecast.

The operational implementation of COAMPS at ARAC includes a very fast method for defining the grid location, allows hourly forecast products to be used soon after being generated rather than after the full model execution is completed, and allows use of up to 6 processors on ARAC's Dec ALPHA computers. A 72-hour forecast over a large 2-nest area takes about 8 hours using 5 processors.

The advantages for ARAC of using COAMPS include its high resolution in space and in time, and the model's accurate representation of a wide range of scales of atmospheric motion. ARAC uses data from COAMPS whenever possible to represent the meteorological conditions in an area of interest. If an event occurs in an area where ARAC is running COAMPS, ARAC will use either COAMPS data alone, or COAMPS data together with observational data. If ARAC is not running COAMPS over the area of interest, ARAC will use observational data or NOGAPS data until a new COAMPS run can be started over the area.

In addition to emergency response, ARAC often re-analyzes releases, sometimes long after the event[3,6]. To support this, ARAC runs COAMPS for the time and area of the release, based on NOGAPS data archived at LLNL.

The growing use of COAMPS by ARAC suggests a need for ARAC to study COAMPS' accuracy. ARAC has evaluated COAMPS forecasts anecdotally by comparing them with analyzed weather maps, and the forecasts have appeared to be excellent. However until now ARAC had no way to evaluate quantitatively the accuracy of COAMPS. The system described here enables ARAC to make this evaluation.

The purposes of this system are to guide the ARAC operators using the data as to the likely accuracy of the forecasts, to reveal undesirable traits (if any) of the model or the operating system leading to improvements, and to allow quantitative evaluations of the impact of changes to COAMPS, new data sources, new operational configurations or procedures, etc.

II. APPROACH

The current approach used in ARAC's COAMPS Verification System (CVS) is to evaluate the differences between rawinsonde observations of basic parameters (height, temperature, and winds), and COAMPS analyses and forecasts of the same parameters. The next step in the system development will be to compare COAMPS data with surface observations of the same basic parameters.

The CVS performs several procedures:

- Rawinsonde data are collected and stored
- COAMPS forecast profiles are saved
- As needed, differences between the daily rawinsonde and COAMPS data are calculated
- The daily difference files are manipulated to generate average statistical values
- A plotting routine is used to generate graphical displays of the statistical values

A. Operational Procedures

1. Rawinsonde Data Collection. Quality-controlled rawinsonde and surface observations are supplied by FNMOC to ARAC in files which arrive several times each day. The CVS software merges the rawinsonde files valid from 21 UTC - 03 UTC, assigning a valid time of 00 UTC for all the data contained in them. Similarly the files from 09 - 14 UTC are considered valid at 12 UTC. In contrast, each hour's surface observations are maintained in separate files. The CVS performs this function automatically twice each day.

2. COAMPS Data Collection. A feature of COAMPS is its ability to generate vertical profiles of the values of specified parameters at specified locations within the model domain. Part of the CVS setup for a new window is to identify the rawinsonde locations within the domain, and specify these locations in the COAMPS input file. The frequency at which COAMPS generates these vertical profiles is controlled by the user. This is usually set to be 12 hrs, to match the normal rawinsonde frequency.

The CVS software collects profiles valid at the same time, from forecasts of different lengths, e.g. it stores in the same file the 00-hr forecast from the latest COAMPS run, the 12-hr forecast profile from the run that began 12 hrs before, and so on, up to the 72-hr forecast. As with the collection of observations, the CVS performs this step automatically twice each day.

3. Difference Calculations. Since all the forecast profiles in each file are valid at the same time, it is straightforward to compare the rawinsonde data valid at the same time to each forecast profile. This yields two sets (00 UTC and 12 UTC) of error values for each day, each set containing error values for forecasts of 00, 12, ..., 72 hrs. The software to generate these daily files is currently run by an operator; eventually this step will also be done automatically.

The comparisons are made at each vertical level found in the rawinsonde file. The COAMPS data are interpolated vertically (linear in the natural logarithm of the pressure) to the pressure levels in the rawinsonde data. An example of this daily set is at Figure 1. The profiles show a moderate amount of variability.

4. Statistics Generation. The twice-daily differences can be combined in any way desired. For operations the usual practice is to generate monthly statistics. Also, we generally calculate the statistics only at the 11 standard pressure levels from 1000 to 100 mb, because all rawinsonde reports should include data at these levels.

Separate files are created for each of the forecast lengths, for each of the locations, for each statistic (root mean square error, bias, and geometric mean bias) and for each variable (height, temperature, wind speed, wind direction, and the u and v wind components.) Plotting all the forecast lengths on the same figure reveals the way COAMPS' behavior changes in time. An example is at Figure 2.

Next, files are created combining the results for the various locations, but still showing results for each forecast length for each statistic. Finally a single file is created, combining the results from all locations at all forecast hours, for each statistic. An example is at Figure 3. In this case only a single location was used, but the system allows use of as many locations as desired.

5. Plot Generation. The CVS uses an NCAR (National Center for Atmospheric Research) graphics package to create plots of all the generated files. The figures in this paper were created using the PV-WAVE language.

B. Intensive Collection Study

The CVS is adaptable to new configurations to evaluate COAMPS forecasts. For example, an intensive sampling period of the Atmospheric

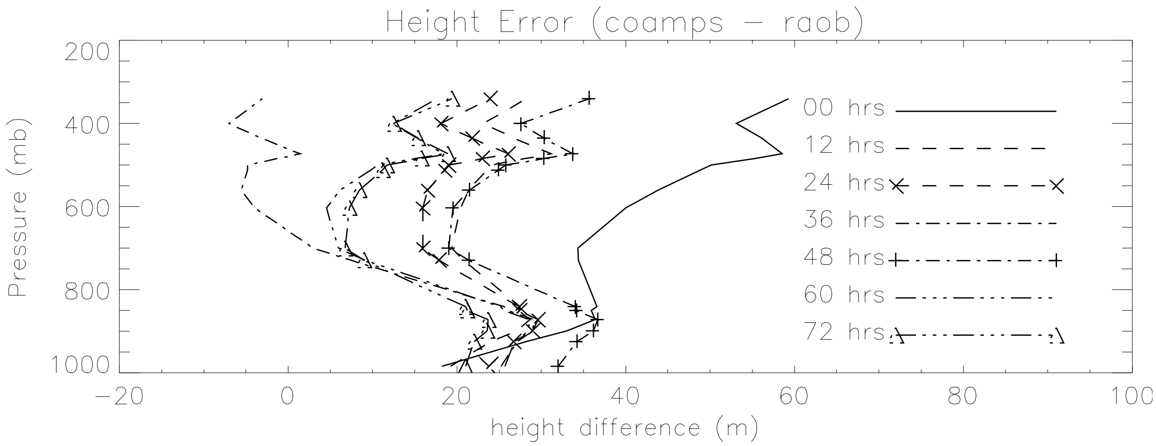

Figure 1. Height errors for COAMPS forecasts valid at 00 UTC on 30 March 1999 at Oakland CA, for forecasts of 00, 12, 24, 36, 48, 60, and 72 hrs.

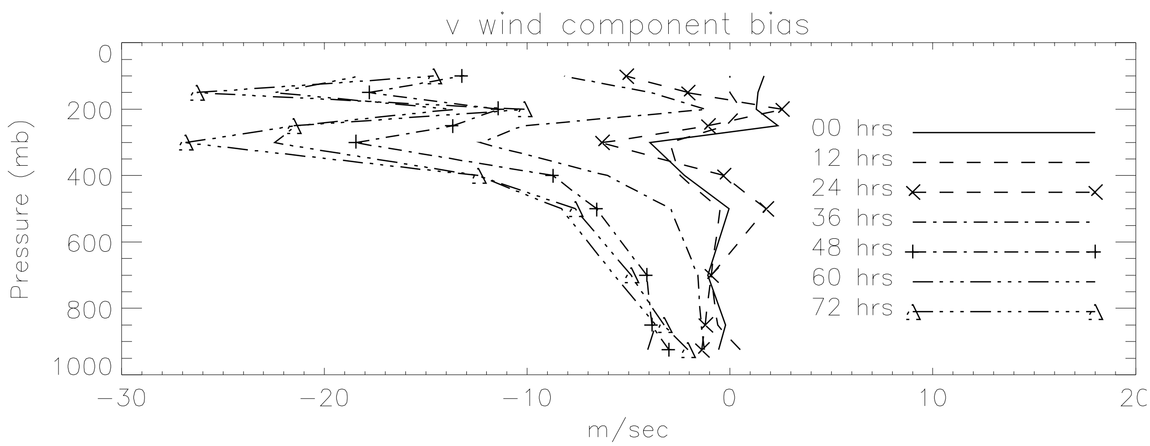

Figure 2. Average bias of the v-wind component for March 1999 at Oakland CA, for forecasts of 00, 12, 24, 36, 48, 60, and 72 hrs.

Radiation Measurement (ARM) project was conducted in March 1999. Rawinsonde soundings were taken at 5 locations in the ARM Oklahoma-Kansas region, at 3-hr intervals, from 1-22 March 1999. A COAMPS window was set up over the region, and 72 hr, 2-nest forecasts were made through the intensive sampling period. These forecasts did not use data assimilation, in order to simulate the behavior of COAMPS in newly-defined locations.

To match the increased rawinsonde frequency, the CVS was modified to generate statistical data at 3-hr intervals. The increased data frequency allows closer examination of model behavior. For example, Figure 4 shows how the temperature bias at low-levels increased almost monotonically from 0 to 72 hrs. This pattern was not seen in the Oakland California data,

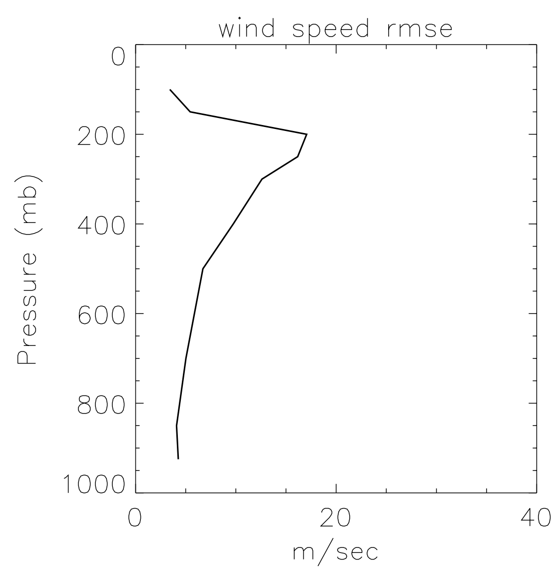

Figure 3. Wind speed rmse for all locations for all forecast hours, for April 1999.

indicating the model's performance in the ARM region may have been affected by incorrect representation of local surface conditions (e.g., ground wetness, snow cover, or albedo).

III. SIGNIFICANCE AND RESULTS

The CVS can provide valuable information to users and developers of COAMPS by revealing systematic trends in its behavior. For example, as a general rule COAMPS seems to remain quite accurate for the first 24-36 hrs, allowing users higher confidence in its results during that period. Developers and maintainers can use results such as those in Figure 4 to identify areas where improvements are most needed.

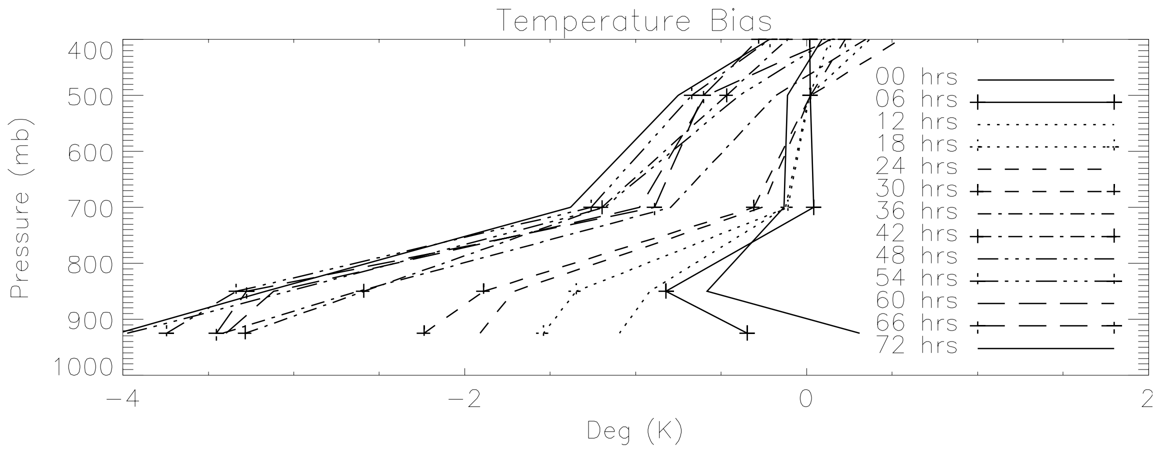

Figure 4. Average low-level temperature bias for 1-22 March 1999 for the five ARM sounding locations, for forecasts of 00, 06, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66 and 72 hrs.

ACKNOWLEDGMENTS

The author is grateful to Ric Cederwall and John Yio for their assistance in obtaining the ARM rawinsonde data. This work was performed under the auspices of the U.S. Department of Energy Lawrence Livermore National Laboratory Contract No. W-7405-ENG-48.

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